OPERATION & MAINTENANCE FOR QUALITY INDOOR AIR

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ABSTRACT

The results of numerous Indoor Air Quality (IAQ) building investigations conducted by the Georgia Tech Research Institute have shown that building Operation and Maintenance (O&M) is a very common source of IAQ problems. This paper presents the protocol used by Georgia Tech in conducting IAQ investigations, including a summary of four example investigations and highlights of important O&M areas to ensure quality indoor air.

INTRODUCTION

Demand for indoor air quality (IAQ) building assessments has increased significantly in recent years. This increase has been stimulated by the sealing of the indoor environment for energy conservation, the introduction of more synthetic materials in the building environment, and increased occupant awareness of their environment. To address this need, the Environmental Monitoring Branch of the Georgia Tech Research Institute has conducted more than thirty "sick building syndrome" (SBS) studies primarily on commercial and institutional buildings. The most common source of IAQ problems identified in these studies has been the lack of [illegible] custodial services, renovation procedures, smoking policies, etc. Investigations by others have also indicated inadequate maintenance as a cause for SBS or building related illness (BRI) (1, 2, 3, & 4). This paper presents the O&M deficiencies found in four recent IAQ investigations.

INVESTIGATIVE PROTOCOL

Georgia Tech's current investigative protocol for buildings with potential SBS or BRI is to conduct a one-day on-site consultation with building management and building occupants. Based on the one-day consultation, a hypothesis of the problem source or sources is made and recommendations for correction or further testing are made. The Georgia Tech investigation team includes an HVAC engineer and a chemist, both of whom are trained in IAQ diagnostics. The one-day consultation includes a meeting with the building management and operating staff, informal interviews with occupants, physical inspection of the building including the HVAC system, and limited IAQ measurements such as microbial swabs, CO_2, and outside air ventilation measurements as needed. Blanket questionnaires of all building occupants are not conducted to avoid hysteria among building occupants. Problems identified by this visit are relayed to building management the same day and this is followed up by a formal report of findings and recommendations. If building management does not contact Georgia Tech for additional testing, follow-up with building management is conducted to assess the status of the original IAQ problems.

This procedure, rather than conducting full scale air sampling in each case, provides a relatively low cost method for building owners and managers to quickly resolve many of the common IAQ problems before they become more serious or at least to know what additional testing is appropriate. In most cases, implementation of the recommendations of the one-day consultation does alleviate the IAQ problems.

INVESTIGATION SUMMARIES

The following is a brief summary of four typical investigations which have been conducted since August 1989. Occupants in each of these buildings exhibited some or all of the common IAQ complaints such as [illegible] contacted several months after the written report was issued. In each case, the occupants' perception of the IAQ in the building had improved and the number of complaints had been reduced.

<u>Building 1</u>

Building 1 is a 5-story, 20 year old university student center with 140,000 square feet of floor area. Complaints were limited to the fourth floor which consisted primarily of offices and was the area in the building occupied the majority of the working day. HVAC for this floor is provided by three constant-volume, dual-duct systems. The air handlers for each system are located on a 5th floor penthouse and all three are connected to a common outdoor air intake.

The building occupants' complaints consisted of headaches, nausea, respiratory problems, and odors. Occupants indicated that symptoms were not present on days when they did not work in the building. Cooking odors from the cafeteria below were also noted by the occupants.

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The investigation disclosed that the fourth floor had a strong sweet vanilla-like odor throughout. The maintenance staff indicated that the HVAC filter had been sprayed with a unknown deodorizer in response to occupant complaints of unpleasant odors, and that cleaning personnel were using lemon-scented cleaners to clean desk tops. Inspection of the mechanical room disclosed standing water on the floor and clogged condensate floor drains. Six sewer roof vents were located directly in front of the primary outdoor air intake (A possible reason for deodorizing the HVAC filters). On the day of the visit, the HVAC system was in the cooling mode and the hot decks had been manually shut down, thereby reducing humidity control. The maintenance staff indicated that this was done for energy conservation. Relative humidity measurements exceeded 70 percent in most areas. Outside air ventilation measurements indicated 13 CFM per person. Smoking was not restricted on this floor. Occupants in the complaint areas had covered several diffusers with plastic in an attempt stop air flow from the HVAC system. Lighting on the fourth floor, particularly in the complaint area was extremely poor and yellowish. Copy machines were located within many of the complaint offices.

The preliminary assessment recommendations made included:

1. Extend sewer vents above outdoor air intake location.
2. Eliminate the use of deodorizers on HVAC filters and highly scented cleaning products.
3. Move copy machines out of occupied offices.
4. Re-activate the HVAC hot deck and lower cold deck temperature to 50°F in order to lower relative humidities below 60% RH during the cooling season.
5. Increase outside air ventilation to a constant 20 CFM per person.
6. Change lamps and clean or repair lenses to provide more adequate lighting.

<u>Building 2</u>

Building 2 is a large, single-story apparel manufacturing facility (children's clothing), however complaints were only present in a newly constructed design room. The design room is constructed within the walls of the manufacturing facility and was completed seven months prior to the investigation. The room is approximately 1000 square feet and is conditioned by a single zone, roof-top A/C unit with an integrated gas furnace. The design room contained large amounts of sample clothing, bolts of new sample fabric, paint cans, and large, true-white, formica-type finish working tables.

All four occupants of the design room were complaining about severe respiratory problems, asthma-like symptoms, eye irritation, lethargy, laryngitis, bronchitis, and work area odor. One of the occupants had seen a doctor who had placed the occupant on the drug Alupent for allergy-related asthma. One of the occupants complained that the life of her gas permeable contact lens had been decrease by half to only six months. Each of the occupants indicated that symptoms were lessened upon leaving the area, particularly on week-ends when not at the facility. The occupants also stated that the area had a strong new carpet odor during the early months of occupancy, but that it now had a more vinegar-like odor.

The vinegar-like odor was particularly strong to the IAQ investigators. This odor is typical of high formaldehyde concentrations. Formaldehyde emissions are common in new, unwashed, wrinkle-resistant fabrics. The outside air dampers on the roof-top HVAC unit were found completely closed. The HVAC filter was found to be very loaded and the coil was quite dirty.

The outside air dampers were immediately opened to 15 percent or approximately 50 CFM per person in this case. The occupants reported an immediate alleviation of the irritating symptoms and odors.

The preliminary assessment recommendations included:

1. Maintain the outside air supply as adjusted to flush this area and also to insure that this area maintains a positive pressure relative to the manufacturing areas.
2. Establish a monthly inspection of the HVAC roof-top unit for filter replacement and outside air damper setting.
3. Minimize the formaldehyde sources in the design room as much as possible by not storing samples in this area.
4. Periodically test for formaldehyde levels to ensure they are below the ASHRAE recommended levels of 0.100 ppm in the design room (5).

Formaldehyde levels were measured in both the manufacturing and design area about one month after the opening of the outside air dampers. The formaldehyde level in the plant area ranged from 0.03 - 0.14 ppm. The formaldehyde levels in the design area was 0.03 ppm, significantly below the ASHRAE guideline.

<u>Building 3</u>

Building 3 is a multi-tenant twenty-one story high rise office building approximately two years old. The building's total floor area is approximately 460,000 square feet. Complaint areas existed on the 7th and 13th floors. The HVAC system is a variable volume type (VAV) with a single air handler on each floor with medium efficiency filters, serving terminal and power induction units. Outside air is forced into the mechanical room on each floor from one of two shafts. Floors 1-13 are serve outside air from a ground level intake fan, and Floors 14-21 are served from a roof-top intake fan.

Occupant complaints on the 7th and 13th floor consisted of nasal stuffiness, severe upper respiratory irritation, headaches, and eye irritation. There were no complaints of thermal discomfort. There were significant odors of new materials, with consequential occupant complaints, during the first year of building occupancy by occupants throughout the building. These complaints have since subsided, and no remodeling was currently being conducted.

Outside air measurements were taken on the 7th through 18th floors. Floors 13 and below indicated flows less than 7 CFM per person and Floors 14 and above indicated flows greater than 15 CFM per person. In addition, the energy management system automatically lowered outside air quantities to 66% of maximum when outside air temperatures were below 55°F and to 33% when outside air temperatures were below 45°F. During the investigation, the maintenance staff located the problem with the lower floor outside air flows. A manual pneumatic valve which controlled the outside air fan blade pitch had been inadvertently closed. Measurements taken after opening the valve increased flows to greater than 15 CFM per person.

Inspection of the HVAC filters, condensate pans, cooling towers, and mechanical rooms indicated no problems. The roof-top and ground level outdoor intakes were well located to minimize possible contamination from cooling tower spray, building exhaust, and auto exhaust. No differences in lighting, office lay-out, or noise levels were noted between the complaint and non-complaint areas.

The following actions were recommended to be taken for at least a three month period before additional testing is undertaken:

1. Re-balance outside air ventilation rates to at least 20 CFM per person and check this quarterly.

2. Eliminate the practice of lowering outside air ventilation based on outside air temperature. Utilize the capabilities of the energy management system to monitor when space temperatures cannot be maintained and only then temporarily reduce outside air ventilation rates.

Building 4

Building 4 is a modern multi-tenant 12 story office building with a total floor area of 286,000 square feet. This building was approximately five years old at the time of the investigation. The HVAC system is a VAV type with a single air handling unit with medium efficiency filters serving terminal and power induction units. Outside ventilation air is forced into the mechanical room of each floor from a single fan and inlet located on the roof penthouse directly next to the cooling tower.

Only occupants of the 9th floor were complaining of IAQ related symptoms which included eye irritation, sinus infections, sneezing and coughing fits. The occupants also complained of a dirty, musty smell which was particularly strong early in the morning. The majority of the worst sufferers had been diagnosed by a doctor as having allergic reactions to molds. The occupants most severely affected were not the type of people commonly predicted to suffer indoor air related problems. All the victims were young, heathy, athletic individuals who had not previously suffered from allergic type reactions. The complains began approximately four months prior to the investigation, simultaneously with the occurrence of two events: 1) renovation of the 9th floor including drywalling, painting, and carpeting, and 2) widespread pesticide treatment for paper mites in the primary complaint area. These events occurred with the areas occupied. No attempt was made to increase ventilation schedules or to isolate the ventilation in the renovated areas.

Outside air ventilation rate measurements indicated flows in excess of 30 CFM per person. However, in one of the complaint areas, the CO_2 measurement was above 900 ppm. Considering the low occupant density of this area, a lack of ventilation efficiency was indicated. Temperature and relative humidity measurements were satisfactory (between 68-76°F, and 49-61 RH). Microbial swab samples of the 9th floor air handling condensate pan, coil, outdoor air intake, and select diffusers were taken. Standing water was present in the 9th floor air handler. The results of these samples indicated fungal growth on the outside air intake, bacteria growth within the condensate pan and coil, and no growth on the diffusers. The genera which were detected are known to cause allergic reactions. Volatile organic compound (VOC) and formaldehyde levels were measured in both complaint and non-complaint areas. Total VOC levels in excess of 1000 ug/m^3 were found in the complaint areas. Levels in excess of 1000 ug/m^3, the Molhave Number, are considered high enough to result in complaints (6). The formaldehyde levels were within values commonly found in office building, 0.020 - 0.030 ppm, with the exception of one area which exceeded 0.050 ppm. This is below the ASHRAE guideline of 0.100 ppm (5), however previous Georgia Tech investigations have noted sensitive people who have suffered irritation effects at levels above only 0.050 ppm.

No differences in lighting, office lay-out, or noise levels were noted between complaint and non-complaint areas. A large copy machine area was present in the middle of the ninth floor with no special ventilation.

The remedial recommendations included:

1. Immediate cleaning of air handler coils and condensate pans with a 25/75 mixture of chorine bleach and water, and neutralized with a water rinse (with the ventilation system off), and then repeated on a quarterly basis. A monthly inspection to ensure that standing water in the condensate pans did not exist.

2. Start operation of the ventilation system at least one hour earlier than current practice, regardless of weather conditions.

3. Operate the ventilation system 24 hours per day with maximum allowable outside air (as determined by the capacity of the HVAC system) during any renovation projects.

4. Hire an air test and balancing firm to review all supply air flows on the 9th floor and have terminal unit minimums raised to between 5% and 10% of the maximum flow.

5. Confine future use of pest control products as much as possible and apply them only during non-occupancy hours with the ventilation system "on".

6. Vent the printing, copy machine area to the outside.

DISCUSSION

As already indicated, follow-up of these investigations was conducted and the results indicated that the IAQ related problems had been substantially reduced or eliminated by following the recommendations made. The types of complaints and the building conditions described in the previous examples are typical of the many investigations conducted by Georgia Tech to date. In each case, O&M problems with regard to the HVAC system, renovation procedures, and miscellaneous services such as pest control were the primary, or at least contributory, factors in causing the IAQ problem. Of course many other areas of O&M, not discussed in these cases, are also important to indoor air quality, such as repair of moisture damage, and smoking policies. Energy conservation measures often are the cause for indoor air problems, such as turning off the hot deck on Building 1. Correction of many of the problems seen such as loaded air filters and dirty coils, however, will result in energy savings. IAQ and energy efficiency do not have to be opposites. A well operated and maintained building can achieve both high quality indoor air and also be energy efficient.

Most facilities managers have O&M programs primarily to keep their building in operation. These O&M programs should include specific procedures to also ensure good IAQ. The most important areas to be addressed include:

o HVAC Component Cleaning
o HVAC Operation Schedules and Air Balancing
o HVAC Filter Specification and Replacement
o Moisture Damage
o Photocopy Equipment Ventilation
o Renovation Procedures
o Custodial Services
o Pest Control
o Smoking Policies

CONCLUSIONS

Improper building O&M procedures are often the primary cause of IAQ problems. Priority to other issues such as energy conservation has also resulted in some IAQ problems without justification. Increased education and training of IAQ issues and O&M procedures to provide good IAQ for building managers and operators, and building servicing firms such as custodial firms is needed. Based on the favorable results of conducting one-day consultations of IAQ problems rather than conducting full scale testing, this protocol for IAQ investigations is providing a cost effective method to address IAQ problem buildings. Research is needed to develop O&M strategies and protocols which result in quality indoor air for a variety of building types and building operations.

REFERENCES

1. Gibbs, L.M. 1987. "Indoor air problems at an academic research institution." Proceedings of the ASHRAE IAQ '87, Practical Control of Indoor Air Problems, pp. 173-177. Atlanta:American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

2. Morey, P.R. 1988. "Microorganisms in buildings and HVAC system: a summary of 21 environmental studies." Proceedings of the ASHRAE IAQ '88, Engineering Solutions to Indoor Air Problems, pp. 10-21. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

3. Rask, Dean R., and Lane, Charles A., 1989 "Resolution of the sick building syndrome: part II, maintenance." Proceeding of the ASHRAE IAQ'89, The Human Equation: Health and Comfort, pp 173-178. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

4. Woods, J.E.; Janssen, J.E.; Morey, P.E.; and Rask, D.R. 1987. "Resolution of the 'sick' building syndrome." Proceedings of the ASHRAE IAQ '87, Practical Control of Indoor Air Problems pp. 338-347. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

5. ASHRAE. 1989. ASHRAE *Standard 62-1989,* "Ventilation for acceptable indoor air quality." Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

6. Molhave, L. 1985. "Volatile organic compounds as indoor pollutants." Indoor Air and Human Health, Chilsea, MI: Lewis Publishers.